Report R3.1
“Preliminary spectrum scenarios and justification for WRC Agenda Item for 5G bands above 6 GHz”

METIS-II

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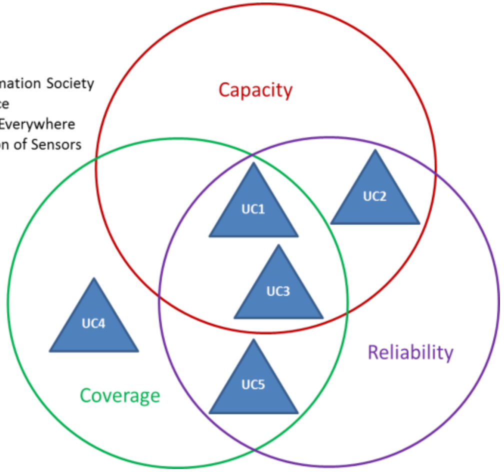
Contents

METIS-II 5G use cases and their impact to spectrum

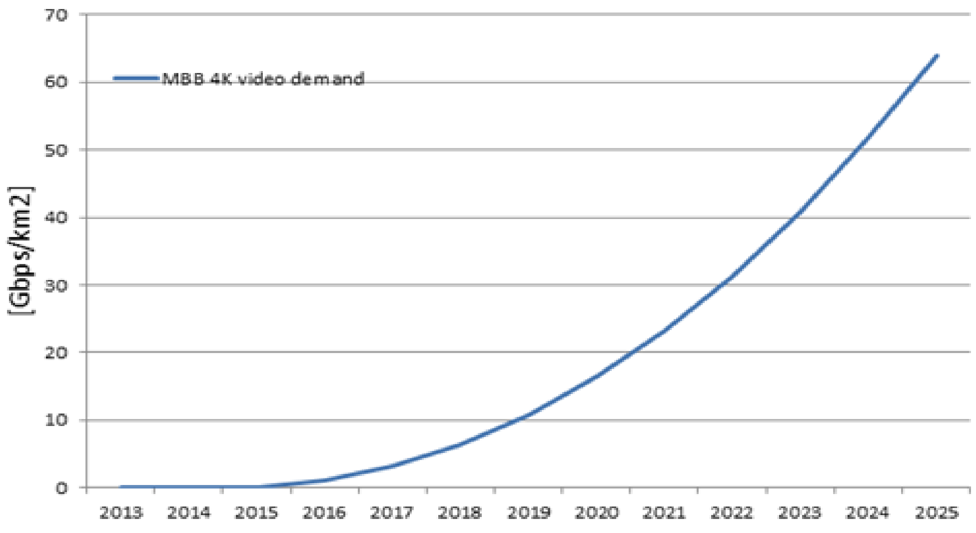
Use case		Scope of Requirements (Network/User Perspective)	Scope of Services (Service Perspective)	
xMBB mMTC	Dense Urban Information Society	Experienced user data rate / Traffic vol. per subscriber / Nb. of users & devices / Energy efficiency	Broad range of communication services covering needs related to both indoor and outdoor urban daily life (excl. office and factory)	*METIS-I UC enriched by NGNM Mobile Video Surveillance UC*
xMBB	Virtual Reality Office	Experienced user data rate/Traffic volume per subscriber/ Latency	Broad range of communication services in in the (indoor) office context	*METIS-I UC*
xMBB	Broadband Access Everywhere	Experienced user data rate / Availability / Mobility / Energy efficiency	Full coverage topic addressing outdoor/indoor communication needs especially in rural areas	*NGNM Use-Case 50+ Mbps everywhere incl. METIS-I Blind Spot TC*
mMTC	Massive Distribution of Sensors and Actuators	Availability / Number of devices / Energy efficiency	Broadest range of IoT services covered	*METIS-I UC Massive Deployment of Sensors and Actuators*
xMBB uMTC	Connected cars	Latency/ Reliability / Mobility	Strong expectation from the (automotive) industry Belong to the first uMTC services expected to be commercialized	*METIS-I UC on traffic efficiency and safety completed by MBB aspects*

UC1 – Dense Urban Information Society
UC2 – Virtual Reality Office
UC3 – Broadband Access Everywhere
UC4 – Massive Distribution of Sensors and Actuators
UC5 – Connected cars



- **Capacity** to cope with high traffic per cell → high bandwidth
- **Coverage** to ensure the availability of 5G everywhere → lower frequencies
- **Reliability** to fulfill the demands of critical services, requiring stable & predictable operation conditions → dedicated spectrum.

EXAMPLE CASE 1: Spectrum bandwidth demand analysis for the xMBB application 4K video



Year	Gbps/km^2	Spectrum bands used in the simulation	Bandwidth required for the DL
2015	2	2.6 GHz, 3.5 GHz	80 + 80 MHz
2025	60-70	2.6 GHz, 3.5 GHz, 10 GHz	80 + 80 + 500 MHz

Example case of xMBB 4K-video traffic up to 70 Gbps/km^2 in the year 2025 shows that bandwidths of at least 500 MHz per operator is needed if the10 GHz band is used.

EXAMPLE CASE 2: Spectrum bandwidth demand analysis of ultra-reliable Machine Type Communication (uMTC) services

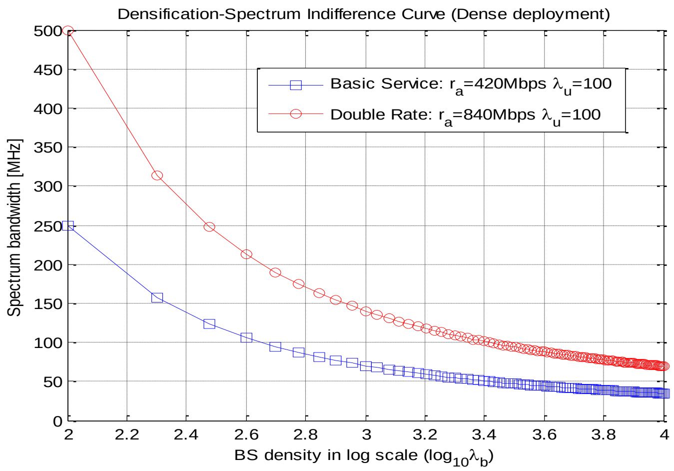
Parameters	Example 1	Example 2
Radio interface delay ( )	200 µsec	100 µsec
Access probability ( )	50%	10%
Packet size ( )	10 Byte	1000 Byte
Baseband Spectral efficiency ( )	5 bps/Hz	1 bps/Hz
Bandwidth demand	**160 kHz**	**800 MHz**

Due to the overall impact of latency and reliability requirements and the amount of devices at the same time, uMTC also need bandwidths in the order of several hundreds of MHz.

Technical rate of substitution approach for wireless networks

The capacity of wireless networks can be basically increased by

1. network densification,
2. higher spectrum efficiency
   (e.g. with multi-antenna techniques)
3. larger spectrum bandwidth.

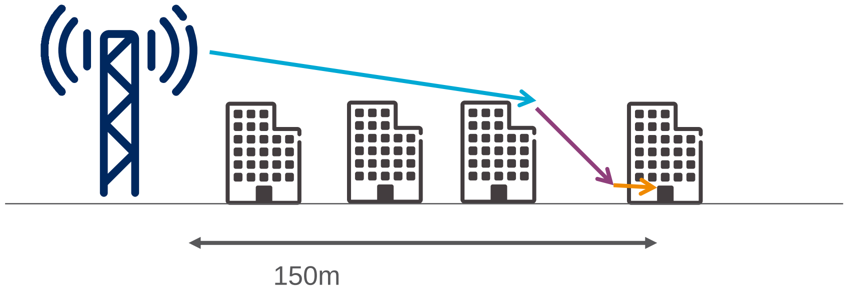


The curves become almost parallel as the BS density increases. This means that it is nearly impossible to increase the user data rate with the densification alone.

These 3 elements are exchangeable in macro-cell environments. However, in dense deployments, spectrum becomes the most effective solution for providing high capacity.

5G mobile coverage provisioning in different frequency ranges

Outdoor to indoor coverage analysis for 5G spectrum



Key parameters assumptions

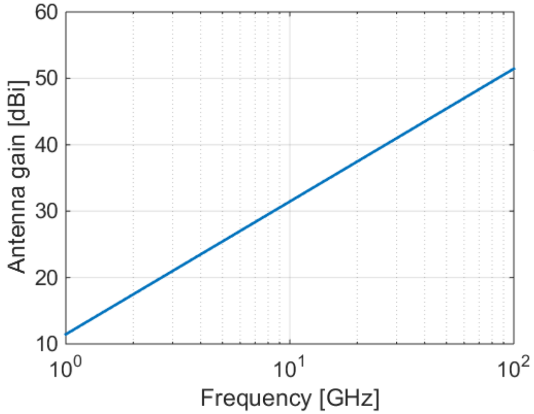
Max. transmit power [W]	Antenna area [m^2]	Solid angle to cover	Distance from BS [m]	Coverage type
40	1 x 0.1	120° x 10 °	150	NLOS, outdoor to indoor

Two studies were performed:

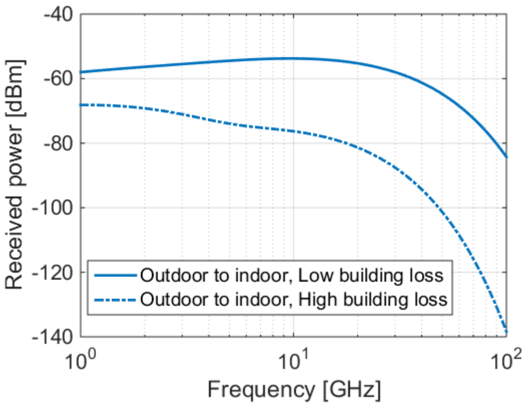
1. Ideal case without practical limits for antenna gain, transmit power and Electromagnetic Field (EMF) exposure,
2. Practical case where those limits were taken into account.

Due to the fact that building penetration depth strongly decreases with increasing frequency, the lower part of spectrum between 6-30 GHz is suitable for outdoor to indoor coverage.

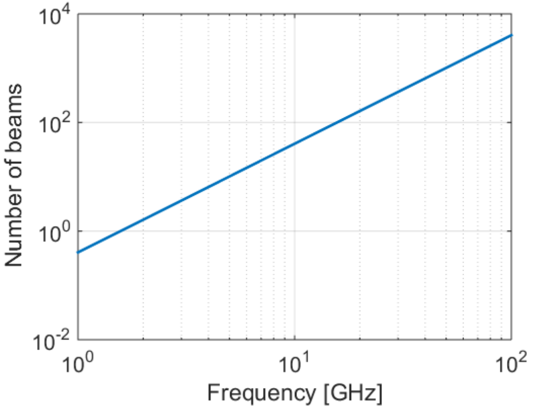
5G mobile coverage provisioning: Study 1 - Ideal case



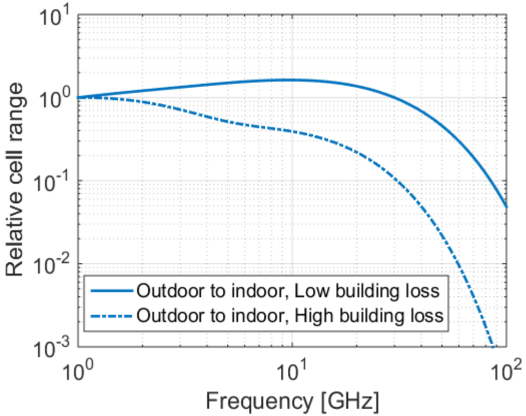
Assumed ideal beamforming gain for a fixed antenna area.



Downlink received power at cell edge versus frequency. Received power decreases even with ideal antenna gain after a certain frequency range.

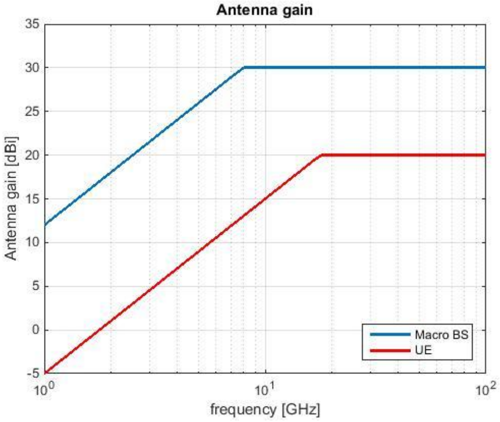


The number of beams needed to cover cell area of interest.

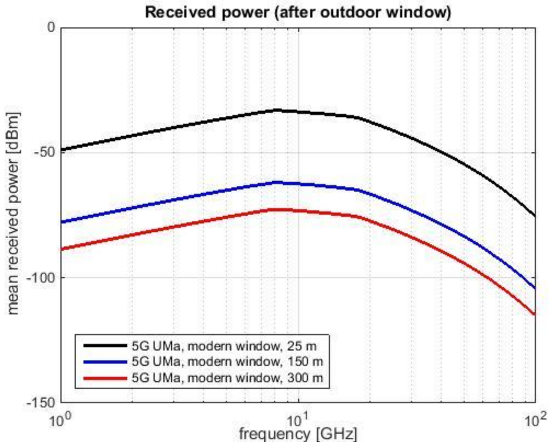


Downlink cell range versus frequency. This indicates that required network densification to cover the area grows with higher frequency.

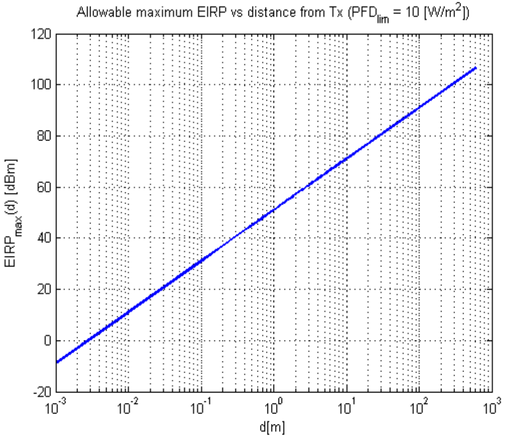
5G mobile coverage provisioning: Study 2 – Practical case



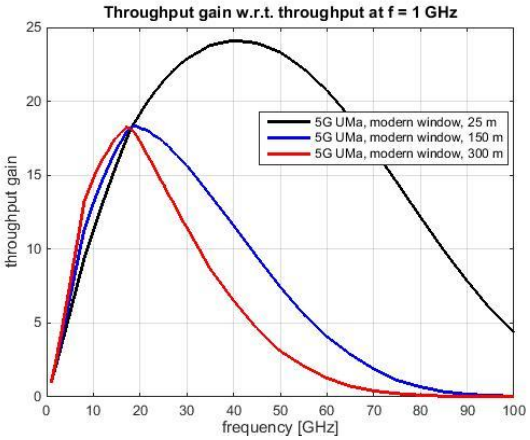
Antenna beamforming gain for a fixed antenna area: Extremely high antenna gains may not be achievable due to challenging management of antenna beams.



Downlink received power versus frequency. Received power decreases after a certain frequency.



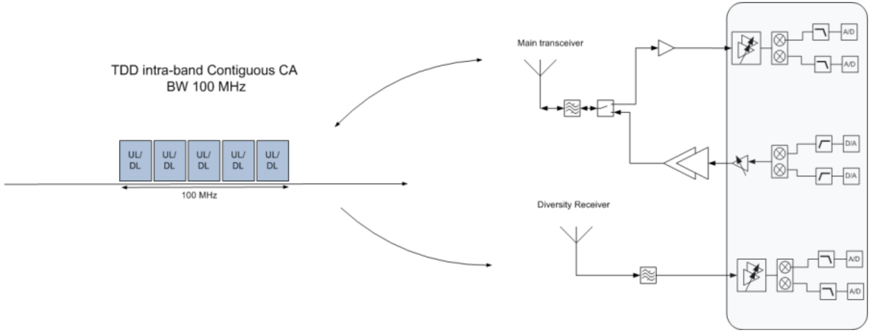
Maximum permitted EIRP as a function of the distance from the transmitter, such that EMF exposure limit given by PFD = 10 W/m^2 is not crossed.



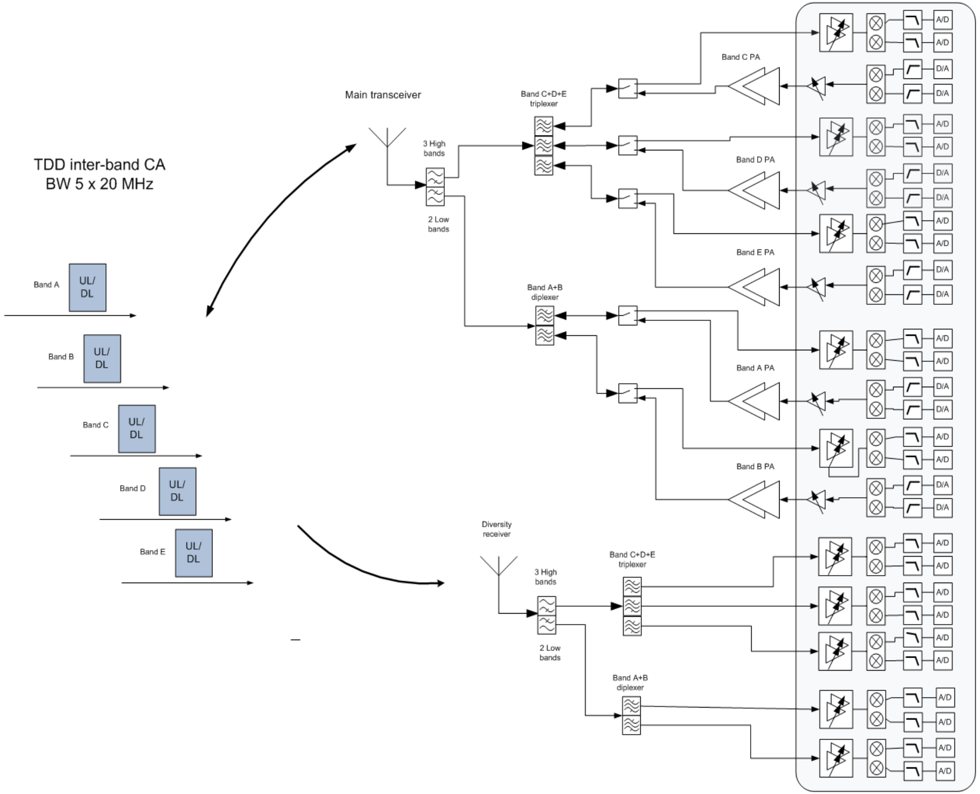
Throughput gain versus frequency. Even with increased channel BW for higher frequencies, throughput decreases after a certain frequency.

Carrier aggregation versus contiguous spectrum bands

Transmitter / receiver implementation for one contiguous band



Transmitter / receiver implementation for five fragmented bands



Contiguous spectrum bandwidth offers advantages with regard to device complexity, signaling, guard bands and interference.

Existing wireless technologies, initial trials and sharing aspects for bands above 6 GHz

- Wireless technology implementations that enable the use of millimeter waves, e.g. for ultra-high capacity P2P / low mobility applications in LoS conditions, were covered.

- Channel and propagation measurements performed at 28 GHz have demonstrated the suitability of centimeter waves for mobile outdoor communications.

- Initial considerations of sharing aspects between 5G and existing services above 6 GHz were done. More studies are needed.

Summary

- 5G service requirements are challenging future mobile networks with regard to coverage, capacity and reliability.
- Example cases for different services indicate demand of several hundreds of MHz per network.
- For capacity increase, spectrum and the other two elements (network densification and technical innovations) are exchangeable in macro-cell environments. However, in dense deployments, spectrum becomes the most effective solution.
- As building penetration depth strongly decreases with increasing frequency, the lower part of the spectrum between 6 -30 GHz is suitable for outdoor to indoor coverage.
- Contiguous spectrum bandwidth offers advantages with regard to device complexity, signaling, guard bands and interference.
- Field trials and existing non-mobile technologies indicate the feasibility to use spectrum above 6 GHz also for mobile applications. Technology innovations are required.
- **Spectrum amount of several GHz is required, to be sought in a combination of different suitable frequency bands in different spectrum parts in the whole range up to 100 GHz.**